Artocarpus altilis (S. Park.) Fosb. Breadfruit, Breadnut

Moraceae Mulberry family

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John A. Parrotta

Artocarpus altilis (S.Park.) Fosb., commonly known as breadfruit or panapén in Spanish (sterile varieties), breadnut, or pana de pepitas in Spanish (seed-bearing varieties), and by several other common names, is a medium-sized evergreen tree with a straight bole, smooth brown bark, and an open crown of large, deeply lobed leaves (fig. 1). Native to the Pacific region from Southeast Asia to Polynesia, breadfruit and breadnut are cultivated throughout the Tropics principally for their edible fruits, which are produced in abundance. The most widely cultivated varieties (breadfruits) produce large, seedless fruits weighing up to 5 kg. Seeded varieties (breadnuts) are cultivated primarily in the Pacific and Caribbean islands. Breadfruit and breadnut are sometimes considered to be distinct species, although most botanists consider them as a single taxon.

HABITAT

Native and Introduced Ranges

The native range of breadnut includes Malaysia, Indonesia, the Philippines, and Melanesia between approximate latitudes 10° N. and 20° S. Seedless varieties (breadfruit) are native to the Polynesian Islands of the Pacific Ocean located between latitudes 5° N. and 15° S. (fig. 2). Among the hundreds of distinct varieties of breadnut, there is a general trend toward decreasing seed size from the western to eastern parts of the species' native range, suggesting that eastern Melanesia may be the center of origin for the seedless Polynesian varieties (breadfruit). Before the period of extensive European exploration and trade in the Pacific area during the 18th century, breadfruit had been introduced to a number of islands outside its native range including Hawaii and the Marshall Islands (*32*). This species may have been introduced to Mexico and Central America from the Philippines during the 16th and 17th centuries, but it was probably not until the late 18th century that it was brought to the West Indies from its native Pacific range by French and English traders and explorers. Perhaps the best documented introduction of breadfruit to the Caribbean was that made by Captain Bligh who brought plants to Jamaica and St. Vincent from Tahiti in 1793. Since then, breadfruit has been cultivated and has become naturalized throughout the humid Tropics. In Puerto Rico and the Virgin Islands, breadfruit is cultivated on most site types except upper montane regions. Though less extensively cultivated than breadfruit, breadnut is grown throughout its native range, in the Caribbean, parts of Central America, and Brazil.

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Climate

Breadfruit and breadnut grow best under humid tropical conditions on sites receiving between 1500 to 2500 mm of annual rainfall, although trees can be grown on sites with an annual rainfall of 1200 mm (*36*). In its native and introduced ranges, temperatures vary from 18 to 32 °C throughout the year (*15, 18*).

Soils and Topography

Artocarpus altilis is a lowland and lower montane tropical species adapted to deep, well-drained soils. In its introduced range, it has become naturalized at elevations up to 700 m and occasionally to 1,000 m (*15, 18, 22*). It grows poorly on

Figure 1.—*Breadnut,* Artocarpus altilis *(S.Park.) Fosb., growing in Puerto Rico.*

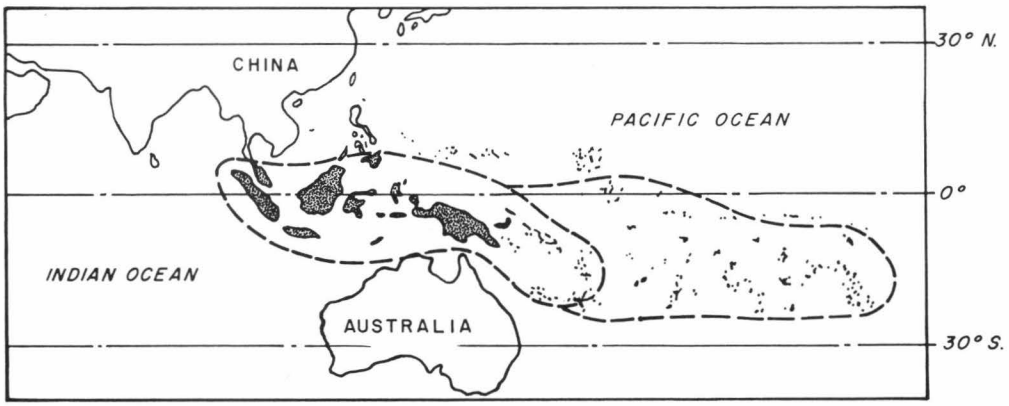

Figure 2.—*Shaded area represents native range of* Artocarpus altilis *(S.Park) Fosb. Inner smaller ring represents the apparent native range of seeded varieties (breadnut), and larger outer ring includes the apparent native range of sterile varieties (breadfruit).*

seasonally flooded soils (*36*) but can survive on very shallow soils such as those that develop on calcareous parent material on the coasts of many Pacific and Caribbean islands. Growth rates on such sites, however, are slow (*35*).

Associated Forest Cover

On the Pacific island of Rota in the Commonwealth of the Northern Mariana Islands, *A. altilis* is a very common component of native limestone rain forests. In these forests, it grows in a codominant position in association with *Claoxylon marianum* Muell.-Arg., *Elaeocarpus joga* Merr., *Ficus prolixa* Forst. f., *Guettarda speciosa* L., *Hernandia labyrinthica* Tuyama, *Neisosperma oppositifolia* (Lam.) Fosb. & Sachet, *Pisonia* spp., and *Serianthes nelsonii* Merr. (*12*).

In Papua New Guinea, breadnut grows in species-rich lowland rain forests in association with *Alstonia scholaris* R. Br., *Dracontomelum mangiferum* Blume, *Garuga* sp., *Octomeles sumatrana* Miq., *Pometia pinnata* Forst., *Pterocymbium* sp., and *Terminalia catappoides* White & Francis (*22*).

In Puerto Rico, breadfruit and breadnut are commonly found in secondary forests on abandoned farm sites in association with *Andira indermis* (W.Wright) DC., *Genipa americana* L., *Guarea guidonia* (L.) Sleumer, *Mangifera indica* L., and *Tabebuia heterophylla* (DC.) Britton (author, personal observation).

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Breadfruit and breadnut flowers are monoecious, the male and female flowers growing on the same tree. Trees normally begin bearing fruit between 4 and 7 years of age (*27*). The male flowers develop on cylindrical, yellowish to brownish spikes 12 to 40 cm long and between 2.5 and 5.0 cm in diameter. Male flowers are 1.5 mm long and consist of a two-lobed calyx and a single stamen. Female inflorescences are ellipsoid or globular, measuring about 6 to 7 cm long and 4 cm in diameter. Female breadnut flowers, approximately 1 cm long and 1.6 mm wide, are composed of a tubular, conelike, and pointed calyx projecting 6 mm, and a pistil with a sunken one-celled, one-ovuled ovary and two-lobed style. The (sterile) breadfruit flowers project only about 0.8 mm.

In the Caribbean region, flowering and fruiting of breadfruit occur throughout the year (*24*), whereas breadnut production is more seasonal (*5*). Within individual breadfruit trees, fruiting is episodal and tends to occur once or twice a year.[1] In Trinidad, breadnut production is continuous between March and September, with maximum production occurring between May and August (*5*). In Hawaii, breadfruit production is more seasonal than in the Caribbean, with fruit most commonly ripening between June and August (*27*). In breadnut, the male and female flowers become fertile at different times, suggesting that cross-pollination does occur. The flowers appear to be predominantly wind-pollinated, and to a lesser extent, insect-pollinated (*8*).

The multiple fruits of the more common breadfruit varieties are globose or ovoid syncarps. They reach maturity approximately 2 to 3 months after the emergence of the inflorescence (*18*) and usually weigh between 500 g and 3 kg, occasionally up to 5 kg (*27*).

The fruits of the breadnut are oblong or globose, with a yellowish-green hexagonally marked rind covered with fleshy prickles. They measure 10 to 30 cm in diameter and weigh approximately 1.0 to 2.0 kg (*5, 36*). The interior of the fruit has little edible pulp and consists of a mass of brown seeds that are rounded or irregularly flattened by compression (*5*). Individual breadnut fruits contain between 12 and 151 seeds (*5*), although the average seed count for fruits from an individual tree is usually between 50 and 100 (*5, 28, 30*).

Seed Production and Dissemination.—In breadnut, the ripe fruits usually break open after falling from the tree, exposing a mass of seeds, many of which begin germination before fruit fall. Seeds constitute between 30 and 50 percent of total fruit weight (*28*).

[1]Francis, John K. 1993. Personal communication with the author. On file with: International Institute of Tropical Forestry, U.S. Department of Agriculture, Forest Service, Río Piedras, PR 00928-2500.

Breadnut seeds are approximately 2.4 to 3.3 cm long and 1.8 to 2.7 cm broad (fig. 3). Two samples of 30 seeds from Puerto Rico averaged 6.22 ±0.16 and 7.23 ±0.14 g per seed, or between 138 and 161 seeds per kilogram (author, personal observation). In Trinidad, a sample of 1,788 breadnut seeds averaged 7.7 g per seed (*5*).

Seedling Development.—Germination in breadnut is hypogeous. In the nursery, seeds should be sown either on the soil surface or partly buried. Germination occurs up to 3 months after sowing.

Although the seeds commonly bud out while still enclosed in the fruit, an additional 4 to 5 weeks are typically required after sowing before the hypocotyl begins to elongate, which is quickly followed by emergence of the plumule and rapid shoot growth. Seedlings form a stout, deep taproot with a few fine, wiry secondary roots (fig. 3). Natural regeneration by breadnut beneath parent trees is usually very good.

Seedlings reach plantable size (30 cm in height) approximately 7 to 9 weeks after sowing or 3 to 4 weeks after the beginning of hypocotyl elongation (author, personal observation). There are no published data available on early growth rates of breadfruit and breadnut, although local observations in Puerto Rico suggest average annual height growth rates of between 1 and 2 m during the first 7 years.[1]

Vegetative Reproduction.—Breadfruit are propagated vegetatively using suckers, air layers, or root cuttings. Younger, smaller trees about 5 years old or less are an ideal source of root cuttings approximately 2 cm in diameter (*18*). These are cut to lengths of 10 to 15 cm and planted obliquely in loose, sandy soil, covered to a depth of 1 cm, and watered frequently (*36*). Such cuttings usually root easily under warm, humid, shaded nursery conditions, although commercial hormone treatments are sometimes used to increase rooting percentages (*18*). Woody, leafless branch cuttings treated with the plant-growth regulators indolebutyric acid (IBA) and indoleacetic acid (IAA) rooted within 10 weeks of treatment in greenhouse beds under intermittent mist (*19*). Natural reproduction by root suckering is prolific in breadfruit and can occur at distances of up to 30 m away from the base of the stem.

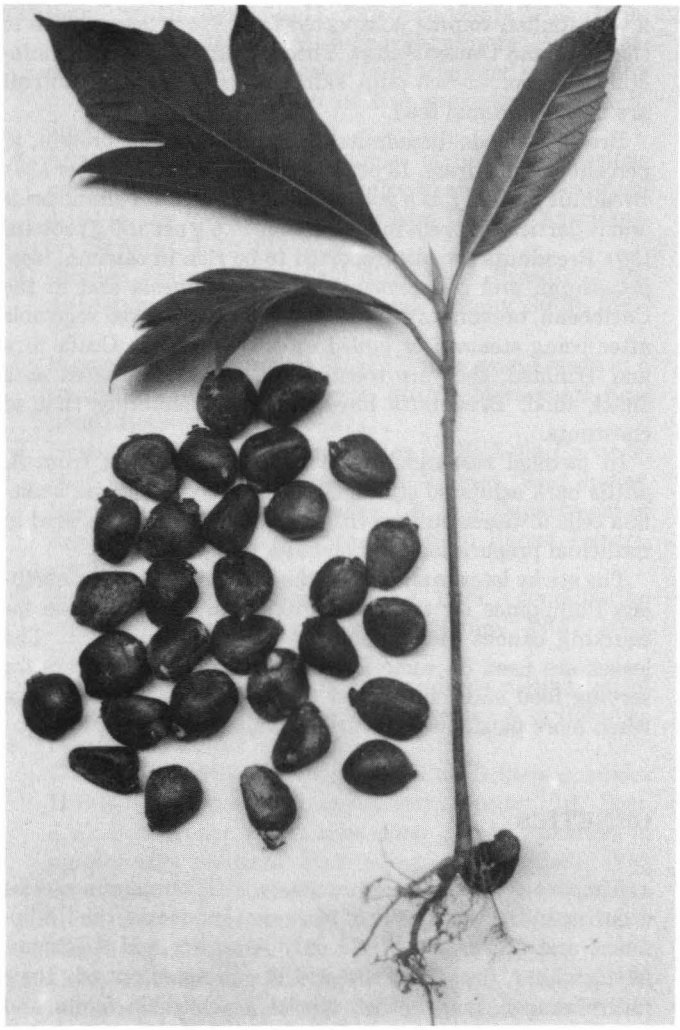

Figure 3.—*Breadnut,* Artocarpus altilis *(S.Park) Fosb., seeds and seedling.*

Sapling and Pole Stage to Maturity

Growth and Yield.—Growth in breadfruit is rapid. Mature breadfruit trees are normally between 12 and 18 m tall, with diameters at breast height (d.b.h.'s) of up to 60 cm (*23*) and relatively few stout branches. The largest breadfruit tree recorded in Puerto Rico was 29.3 m in height with a d.b.h. of 69.5 cm.[2] On the island of St. Vincent, breadfruit comprised approximately 2.5 percent of the total basal area in secondary forests (*6*).

Although generally very similar in appearance, breadfruit and breadnut can be distinguished by leaf shape and fruit morphology. Breadfruit leaves are usually more deeply lobed than those of breadnut, generally have 9 or 11 lobes instead of 7 as in breadnut, and are more hairy. The surface of breadnut fruits is composed of greenish, conical, spinelike projections (one from each flower), whereas that of breadfruit is smoother with a honeycombed texture (*23*). Mature breadfruit trees can produce up to 700 fruits per year (*5*).

Rooting Habit.—Breadfruit trees produce extraordinarily long lateral roots. Lateral roots up to 200 m in length have been reported on 5-year-old trees only 7 m in height (*18*).

Reaction to Competition.—During the first few years, breadfruit and breadnut grow best under light shade (*37*). However, in older trees, full sunlight is required for fruiting (*18*). Breadfruit plantations are typically established at spacings between 8 by 8 m and 10 by 10 m (*18, 36*).

Damaging Agents.—In the Solomon Islands, an unidentified noctuid (Lepidoptera) causes serious damage in breadfruit (*29*). The hemipteran *Rastrococcus invadens* Williams, the most serious polyphagous pest of horticultural crops during the past 10 years in west Africa, has been reported to cause serious damage to breadfruit in Togo and Benin (*2*). In Puerto Rico, several insect species have been reported on breadfruit and breadnut, although none are known to cause

[2]Francis, John K.; Alemañy, Salvador. 1993. The champion trees of Puerto Rico. Unpublished manuscript on file with: International Institute of Tropical Forestry, U.S. Department of Agriculture, Forest Service, Río Piedras, PR 00928-2500.

serious damage (*26*). These include the beetle *Pycnarthrum sp.* (Scolytidae), the hemipterans *Corythucha gossypii* (Fabr.) and *Piezosternum subulatum* (Thunberg), the homopteran *Coccus mangiferae* (Green), and the isopteran *Nausitermes costalis* (Holmgren).

In Western Samoa, Sri Lanka, and the Dominican Republic, fruit rot caused by *Phytophthora palmivora* Butl. is a serious problem in breadfruit plantations, although several resistant varieties have been identified (*17, 33*). In southern India, breadfruit is susceptible to serious damage by fungal pathogens, including twig dieback caused by *Glomerella cingulata* (Ston.) Spauld. & Schrenk (*1*) and fruit rot caused by *Phytophthora* sp. (*34*). In Brazil, a root rot caused by *Fomes lignosus* (Klotzsch) Bres. and a heartrot caused by *Polyporus zonalis* Berk. have been reported (*33*). A leaf spot caused by *Cercospora artocarpi* H. & P.Syd. has been reported in the Philippines (*33*). In Puerto Rico, only three pathogens have been reported on breadfruit: an algal leaf spot caused by *Cephaleuros virescens* Kunze, seedling blight caused by *Sclerotium rolfsii* Sacc., and a rust identified as *Uredo articarpi* Berk. & Br. (*38*).

The sapwood is very susceptible to attack by dry-wood termites (*24*) and powderpost beetles (Lyctus spp.) (*21*) and has a low durability of between 1 and 8 years when in contact with the ground (*21*).

SPECIAL USES

Breadfruit sapwood is yellow or brownish yellow in color, and the heartwood is golden yellow, sometimes mottled with orange. Although it is very soft and light, with a specific gravity of between 0.27 and 0.45 g/cm^3, it is quite firm and strong considering its low density (*21, 24*). There are numerous large pores but no growth rings, and rates of air-seasoning and amount of degrade are moderate (*24*). Shrinkage from green to ovendry weight is 3.6 to 6.5 percent tangential and 2.1 to 4.1 percent radial (*21*). The wood has poor shaping, turning, boring, mortising, and sanding characteristics; planing characteristics are fair, and resistance to screw splitting is excellent (*24*). The wood is not often used except for surfboards, boxes, handicrafts such as toy making, and for fuel (*40*). It may be suitable for light construction, agricultural implements, plywood, pulpwood, joinery, and particleboard (*21*).

Breadfruit is commonly planted in traditional agroforestry systems among shifting cultivators in the lowlands of Papua New Guinea (*3*). These systems typically include several other tree species, notably *Pometia pinnata* Forst. & Forst. f.; sago palms, *Metroxylon sagu* Rottb.; coconut, *Cocos nucifera* L.; and *Gnetum gnenom* L. with more than 30 understory crops, particularly yams, *Dioscorea* spp.; bananas, *Musa* spp.; taro, *Colocasia esculenta* (L.) Schott; and sugarcane, *Saccharum officianarum* L. In Indonesia, breadfruit is planted in agroforestry systems with other perennial crops such as cloves, *Syringa aromaticum* (L.) Merr. & Perry; bananas; and sawo trees, *Manilkara kauki* (L.) Dub. (*11*). In the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, and Samoa, breadfruit is widely used in a variety of traditional agroforestry systems (*10, 12, 13, 14, 25, 41*). In northern Venezuela, it has been used as a shade tree in coffee and cacao plantations along with *Erythrina poeppigiana* (Walp.) O.F. Cook, *Spondias* spp., and *Inga* spp. (*20*). Its use in agroforestry systems has been described in Brazil (*9*).

Breadfruit is eaten as a cooked vegetable either boiled, fried, or baked. Its carbohydrate food value is high, and it is considered to be a good source of vitamin B and a fair source of vitamins A and C (*27*). The calorific value and protein content of breadfruit are 75 to 80 cal/100 g and 1.5 percent, respectively (*15*). Breadfruit chips, prepared like potato chips, are a popular snack in India and parts of the Caribbean. A dessert and preserves are sometimes made from the male flower clusters (*24*). In Micronesia and the Marquesas Islands in the Pacific where breadfruit is a primary foodstuff, it is made into a paste and fermented into a cheeselike substance, which can be stored indefinitely (*4*). Throughout Polynesia, it is eaten with coconut milk, seawater, and lime juice (*23*).

Although breadfruit does not keep well in its fresh state, it can be parboiled and frozen with little or no deterioration in nutritional quality or taste. Industrial processing techniques, specifically dehydration methods, may enhance its potential as a commercially valuable agricultural commodity (*31*). At present, a limited quantity of breadfruit (canned in brine) is exported from Jamaica to the United Kingdom, and a very limited volume is exported fresh from Puerto Rico to the mainland United States. Throughout its range, the mineral- and protein-rich pulp, skin, and core of the breadfruit are used as animal feed.

Breadnut seeds (breadnuts) contain 20 percent protein, 16 percent carbohydrate, 13 percent fat, and 4 percent fiber (*30*). Breadnut protein has a good balance of essential amino acids and is particularly rich in methionine (7.5 g per 100 g protein) (*30*). Breadnuts are also reported to be rich in calcium, iron, potassium, and phosphorus (*28*). In Melanesia and in the Caribbean, breadnuts are usually eaten as a cooked vegetable after being steamed or boiled in salty water. In Costa Rica and Trinidad, they are roasted and salted and eaten as a snack food. Breadnuts have a taste resembling that of chestnuts.

In medical research, three flavonoids isolated from *A. altilis* bark exhibited strong cytotoxic activity against leukemia cells in tissue culture (*16*). The sap is reportedly used in medicinal preparations in Polynesia (*40*).

The sticky latex exuded from the stem is used in the northern Philippines for trapping birds (*7*) and in Polynesia for caulking canoes and fashioning diving goggles (*40*). The leaves are used on some Polynesian islands as platters for serving food and for compost (*40*) and can serve as forage when more palatable feeds are unavailable (*18*).

GENETICS

Artocarpus is a pantropical genus with numerous species occuring in the wet forests of Malaysia, Indonesia, the Philippines, and Melanesia. While only *A. altilis* and *A. heterophyllus* Lam. (jackfruit) are widely cultivated outside their native ranges, many other species yield edible fruits and other nonwood products, and several yield high-quality timber (*39*). Those producing edible fruits include *A. brasiliensis* Gomez, *A. camansi* Blanco, *A. dadak* Miq., *A. elastica* Reinw., *A. glauca* Blume, A. *lakoocha* Roxb., A. *odoratissima* Blanco,

A. *polyphema* Pers., and A. *rigidus* Blume. Species yielding good to high quality timber include A. *altissima J.J.* Smith, *A. anisophylla* Miq., *A. chaplasha* Roxb., *A. dadak, A. glauca, A. hirsuta* Lam., *A. lakoocha, A. lanceaefolia* Roxb., *A. limpato* Miq., *A. polyphema,* and *A. rigidus.*

Botanical synonyms of A. *altilis* include *A. communis* J.R. & G. Forst. and A. *incisus* (Thunb.) L.f. (*24*). There is a high degree of genotypic and phenotypic variation in breadnut, and seed weights and seedling morphologies vary widely among varieties. To date, very little genetic selection or crop-improvement research has been carried out on this species. A breadnut germplasm collection that contains varieties from the Society Islands, Polynesia, Micronesia, and Melanesia has been recently established by the International Plant Genetic Resources Institute.

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